

On the Development of MMCS Containing Copper with Silicon Carbide Reinforcement Using Nanomaterials and Dynamic Compaction

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ON THE DEVELOPMENT OF MMCS CONTAINING COPPER WITH SILICON CARBIDE REINFORCEMENT USING NANOMATERIALS AND DYNAMIC COMPACTION*

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Introduction. Metal matrix composites (MMCs) are promising engineering materials for a wide spectrum of applications. There are many possible matrix-reinforcement combinations including MMCs containing copper or copper alloy matrices [1-3]. The present study is concerned with copper reinforced with SiC particles. The materials studied here were processed from nano-scale matrix powders and consolidated using dynamic compaction.

Materials and processing. Pure copper nano-powder with an average particle size of 70 nm and silicon carbide powder with an average particle size of 10 μm were used in this investigation. The copper nano-powders were produced using the exploding wire technique [4]. Previous work has shown that cohesion between the nano-scale matrix and the reinforcement increases with decreasing particle size. Before mixing with silicon carbide, the nano-powders were agitated using ultrasonic vibration to help break up any powder agglomerations. These powders were then blended with SiC powder and stirred in hexane with simultaneous ultrasonic vibration. The hexane environment prevented oxidation of the copper powders. After stirring, the powders were settled out of the hexane and residual hexane was then removed using a vacuum. This mixture was then dynamically compacted using a magnetic impulse technique. Samples 15 mm in diameter and 15 – 20 mm high were obtained. The resulting microstructure and the evolution of microstructure during processing was then studied using optical, scanning, and transmission electron microscopy.

Influence of processing variables. Microstructural evaluation of material after each processing stage has shown the importance of processing procedure on obtaining high quality material. Nano-powders tend to agglomerate. The ultrasonic agitation step before and during mixing is necessary to break-up these powder agglomerations. Agitation time is a critical variable for obtaining a homogeneous

distribution of reinforcing particles with the absence of denuded zones - matrix regions that do not contain silicon carbide particles. Inadequate agitation time results in the formation of these denuded zones (Fig. 1).

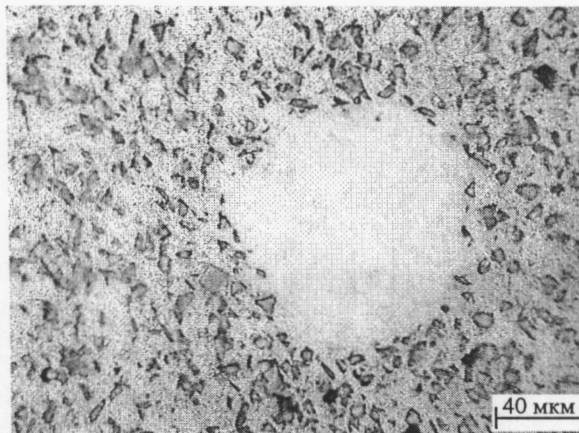


Fig. 1. Microstructure of the Cu-SiC composite showing a zone that is devoid of silicon carbide particles. The de-nuded zone formed in the nano-powder copper matrix because of inadequate ultrasonic agitation time.

Using the processing procedures described above, uniform distribution of reinforcement particles within the Cu matrix can be obtained with the absence of defects. (Fig. 2).

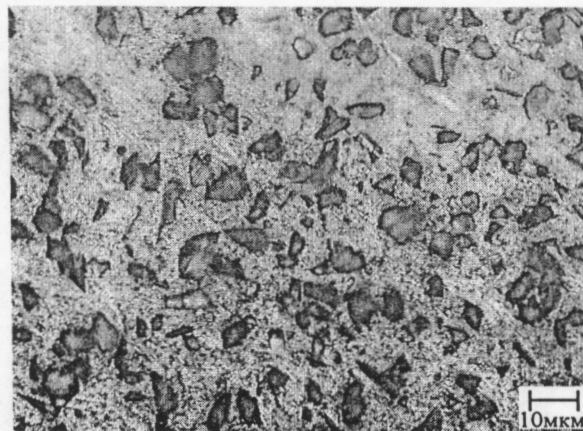
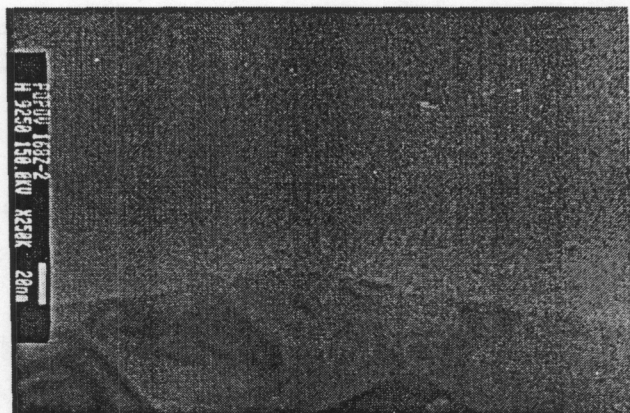
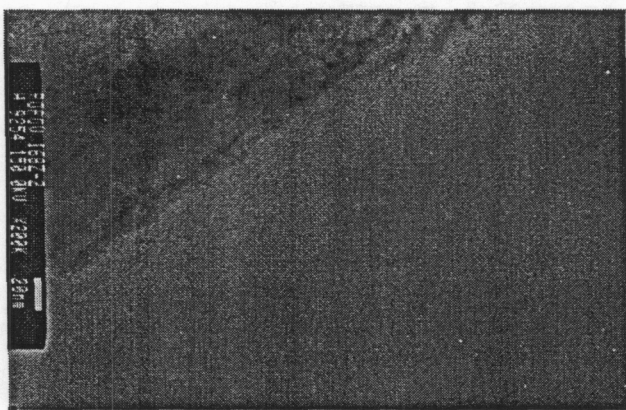


Fig. 2. Uniform distribution of silicon carbide particles within the copper matrix.

Microstructural evaluation. Microstructural examinations of the as-processed MMCs using TEM, SEM and optical microscopy showed dense compaction without any defects such as pores, cavities or impurities. In addition, TEM examination showed that well-defined interfaces between the copper matrix and silicon carbide particles were obtained (Fig. 3a and b). The interfaces did not show any deleterious phases or reaction products.



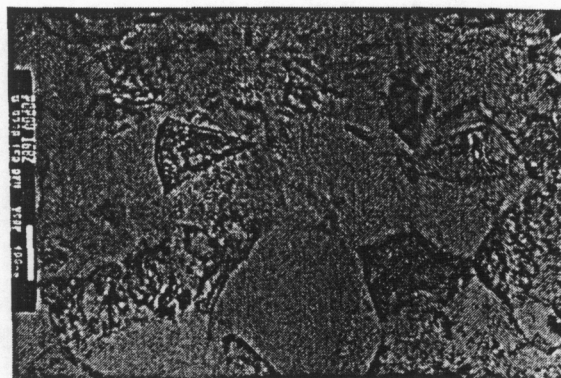
a)



b)

Fig. 3. Interface region between Cu matrix and SiC reinforcement showing dense contact between Cu matrix and reinforcement particles without any defects.

Analysis of cross-sectional surfaces of the MMC showed a homogeneous distribution of SiC particles within the Cu matrix. The magnetic impulse technique produced dynamic compaction of the initially spherical Cu powders into a matrix in which individual particles did not lose their identity. Minimal grain growth was observed during dynamic compaction. As a result, the Cu matrix had a grain size of 100 – 500 nm (Figs. 4a and b).



(a)



(b)

Fig. 4. Transmission electron microscope micrograph showing structure of the copper matrix – low magnification (a), high magnification (b).

This investigation has shown the possibility of manufacturing MMCs using nano-scale Cu powders with silicon carbide particle reinforcement. The powders can be dynamically compacted using a magnetic impulse technique to produce a matrix with nano-scale grain sizes. Because of the fine grain size of the Cu matrix and the dense, defect-free microstructures produced, these MMCs are expected to have excellent properties.

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